Beneficial Use of Vermicompost in Aquaponic Vegetable Production

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Experimental trials were conducted at Windward Community College's (WCC) Freshwater Aquaculture and Aquaponics Research Facility on O'ahu Island. Trials were conducted over the course of several growing seasons to evaluate the effectiveness of aerated vermicompost tea in: 1) alleviating nutrient deficiencies (specifically inter-veinal chlorosis) in growing aquaponic pak-choi, and 2) providing pH buffering capacity to seasoned aquaponic systems. Additionally, mature vermicompost was added to seedling plugs as a replacement to imported synthetic fertilizer and using the growth of the resulting pak-choi plants at harvest as a means of evaluating the treatments in experimental aquaponic systems. These trials were conducted based on increased demand from commercial aquaponic producers to both develop renewable micronutrient supplement strategies that decrease or eliminate reliance on synthetic imports, as well as improve seeding technologies which will utilize renewable, locally available materials.

Aquaponics (the integration of aquaculture and hydroponics) is an emerging technology that serves as a model of sustainable food production. In a recirculating aquaponic system (RAS), liquid effluent rich in plant nutrients derived from fish manure, decomposing organic matter and metabolic byproducts from protein catabolism in fish, fertilizes hydroponic beds providing essential elements for plant growth (Rakocy et al., 2006). Some of the advantages of aquaponics over conventional agriculture include: farming in a relatively small footprint, eliminating the need to lay crop land fallow (thus increasing turnover and yield in a given space), eliminating the need for large and expensive farming and harvesting equipment, elimination of effluent waste released into the environment containing excess fertilizers and other chemicals, increasing plant growth (sometimes as much as 18 times compared to ground control in the case of okra), and extremely low (about 2-4%) water use (Rakocy et.al., 2006). Production of multiple crops via the combination of aquaculture and hydroponic technologies synergizes

Figure 1. CTAHR undergraduate student Genna Daly and interns from Kalani HS sampling pak-choi from experimental aquaponic units at WCC.

the economic value of both enterprises (Rupasinghe and Kennedy, 2010). Furthermore, being independent of the quality or even need for soil for producing crops this technology provides extraordinary freedom to farmers and gardeners alike as to where they may be able to grow their produce.

One of the limitations of commercial aquaponic production has been the reliance on imported synthetic micronutrient and pH buffering supplements to maintain optimal water quality conditions (Rakocy et al., 2006). The current convention is to use inputs such as concentrated potassium hydroxide (KOH) and calcium hydroxide ($Ca(OH)_2$) to counteract the naturally acid-trending aquaponic system resulting in essentially neutral conditions (~pH 7.0). Maintaining the pH near 7 permits a compromise between optimal pH for nitrification by nitrifying bacteria (pH 7-9) and that for optimal availability and absorption capacity of essential micronutrients through roots in hydroponic systems (pH 5.5-6.5) (Rakocy et al., 2006; Tyson et. al., 2008). This strategy also serves the dual purpose of supplementing essential nutrients (i.e., potassium and calcium) while concurrently neutralizing excess acid. Additionally, levels of Fe^{2+} that eventually become dissolved in aquaponic water from fish food are not adequate to support vegetable production and iron must be supplemented in a chelated form (Rakocy et al., 2006).

One of CTAHR's primary goals is to promote sustainable and renewable agricultural practices, which is very much in line with commercial aquaponic producers' desire to develop locally sourced replacements for these synthetic inputs. A promising alternative to this dilemma is vermicompost. Vermicompost is the process or product of composting utilizing a variety of earthworm species. Vermicompost has been shown to enhance plant growth, crop yield, and improve root structure and development in the field (Pant et al., 2009). It is also suspected to have pH buffering capacities in soil. Vermicompost can be applied directly to soil, or seeped in water and made into a "worm tea." Vermicompost tea contains high levels of water-soluble mineral nutrients and microbial metabolites (i.e., organic acids, cytokinins, growth regulators, etc.) that act to enhance nutrient uptake (Pant et al., 2009). Strategies at CTAHR to utilize vermicompost efficiently include: 1) using aqueous compost extracts (compost tea) to extend applications over a larger area, and 2) incorporating compost into seedling media to target applications directly to

Figure 2. Three pak-choi seedling treatments. From left to right; Oasis® cubes, Oasis® cubes with 0.4 g vermicompost, and 1:1 peat:vermicompost plug

the seedling and replace imported materials.

In light of previous positive results with worm tea, the first set of experiments were designed to determine if vermicompost tea could be used to supplement micronutrients and buffer pH in experimental aquaponic systems. There was no difference in yield between pak-choi grown under aquaponic conditions supplemented with worm tea verses a static hydroponic positive control. The worm tea trials confirmed that vermicompost tea (even in the high dose concentration equivalent to an aqueous extraction from 0.5 lb of solid vermicompost per pak-choi plant) was unable to ameliorate nutrient deficiencies in pak-choi grown under aquaponic conditions, specifically inter-venial chlorosis. Worm tea appears to function differently in aquaponic systems than it does under soil conditions.

Figure 3. A pictorial representation of typical yield at harvest from the initial seedling trial. Plants grown with Oasis® cubes only or Oasis® cubes with 0.4 g vermicompost supplement exhibited nutrient deficiencies and were significantly smaller at harvest.

Members of our working group suggested we try a different approach, and take advantage of a physiological adaptation in young plants called "luxury consumption." This mechanism, first described in 1974 (Van den Driessche, 1974), states that luxury consumption is "…the increase in tissue nutrient concentration above the maximum yield, which does not result in further yield increase." In other words, when there are excess nutrients available to seedlings, they can uptake and store them, then mobilize the nutrients to tissues in the future when needed.

Using mature vermicompost and peat mixtures designed by our working group members to replace synthetic imports, a second set of experiments were initiated to try and address the issue of priming seedlings before being grown out in an aquaponic system. The standard operating procedure followed in the tea trials included starting seedlings in Oasis® with no companion fertilizer. Thus, the following seedling trial was designed to address the question of whether yields could be improved by the inclusion of vermicompost in the seeding media, and whether the observed nutrient deficiencies could be prevented via luxury consumption. Three treatments were developed for this set of seedling trials: 1) Oasis® cubes only, 2) Oasis® cubes plus a "dollop" (0.4 g) of vermicompost on top of the seed, and 3) a 1:1 peat:vermicompost plug (Figure 2). The seedlings were added to replicate experimental aquaponic units under identical conditions to those described in tea experiments. A representative image of the results can be seen in Figure 3, and the data on fresh weight have been summarized in Figure 4. Seedlings started in Oasis® cubes alone with no fertilizer resulted in significantly lower yielding plants at harvest than those supplemented with 0.4 g vermicompost and those started in 1:1 peat:vermicompost plugs respectively in both the ebb/flow and raft growing conditions (Figures 3 and 4). Additionally, no nutrient deficiencies were observed in the pak-choi planted in 1:1 peat:vermicompost plugs at harvest, while inter-venial chlorosis was observed in the other two treatments.

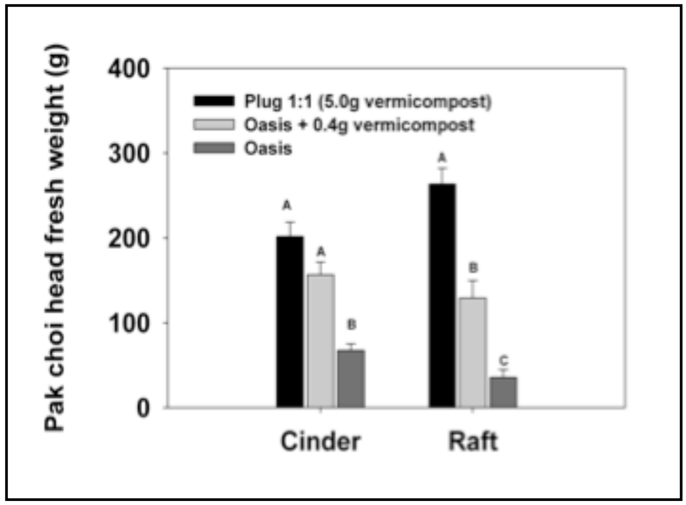

Figure 4. A graphic representation of data collected following the first seedling trial. Pak-choi started in peat:vermicompost plugs grew significantly larger in both the ebb/flow and raft components of the aquaponic

Following this initial seedling trial, several additional dose-response trials were conducted to determine the minimum vermicompost requirement for optimal seedling results in aquaponic systems. Using the CTAHR experimental systems at WCC, an experiment testing the growth of seedlings in aquaponic systems started in Oasis® cubes or peat containing 0, 5, 10, 20, or 50% vermicompost by weight was conducted. In one trial, plants were harvested at 3 weeks post emergence (Figure 5A) and in a follow-up trail others were sampled at 6 weeks (Figure 5B). The inclusion of vermicompost, even at the 5% level, in plugs resulted in a significant (double) increase in fresh weight at harvest compared to controls (Figure 5B).

A commercial aquaponic vegetable producer (i.e., Mari's Garden) agreed to conduct on-farm trials to validate the proof of concept at commercial scale. The testing proved to be fortuitous as the commercial producer was at the time seeking organic certification of his plant crops and the use of the Oasis® cubes, which is an accepted practice in hydroponics but is not acceptable for organic certification because of its synthetic origin. The on farm test results were significant enough that the use of Oasis® cubes for production of seedlings has been discontinued paving the way to organic certification. Collaborative efforts with the owner (Fred Lau) of Mari's Garden (Figure 6) have resulted in a seedling plug that substitutes the use of vermicompost with Sustane® (turkey compost) that significantly reduces the cost of the seedling plug and is currently being utilized on farm. The project work group continues to work with the farm to develop more cost effective seedling production methods that targets the utilization of only locally produced products that would ultimately result in the desired outcome of self reliance in producing our own food.

References

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Figure 5A

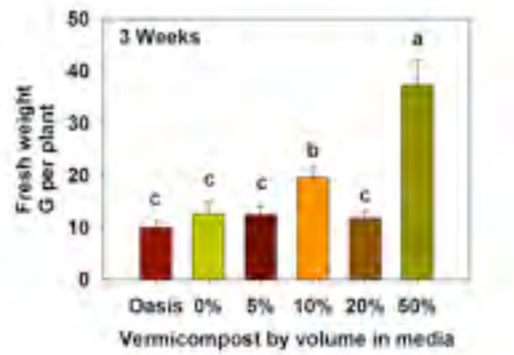

Figure 5B

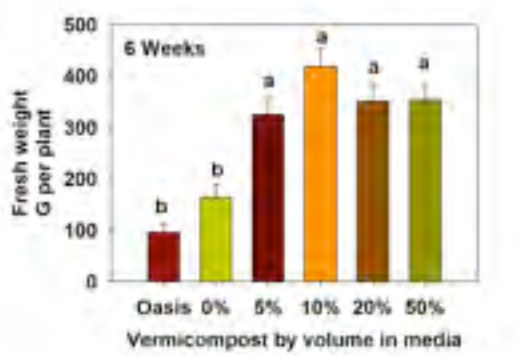

Figure 5. A graphic representation of data collected in the second seedling trial, expressed as mean +/- SEM. This dose-response experiment clearly shows the benefit of even a 5% supplementation of vermicompost in seedling media at harvest.

Figure 6. Theodore Radovich (second from right) explains the properties of the different seedling media to be used for the on farm site test at Maris Garden. Owner (Fred Lau) of Mari's Garden is second from the left along with son and fall 2011 CTAHR graduate Brendon Lau (middle).